

SYMPOSIUM ON FUEL CELLS
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ADVANCES IN FUEL CELL TECHNOLOGY

By

Anthony M. Moos
Leesona Corporation

One-hundred twenty years after Sir William Grove, the father of the fuel cell, demonstrated that fuel cells using gaseous fuels were possible, a Symposium on Fuel Cells was organized and held by the Gas and Fuel Chemistry Division of the American Chemical Society at the 136th National Meeting in September, 1959. The papers presented at that Symposium were collected and published by Professor George Young in June, 1960. This book represents the first authoritative source of information on these revolutionary energy conversion devices.

In the spring of 1960, a technical and economic analysis of developments and opportunities in electrochemical fuel cells under the title, "Fuel Cells - Power for the Future", was published by Research Associates, a group of graduate students at the Graduate School of Business Administration of Harvard University. This book is an optimistic, but excellent, reference source on the economic potential of fuel cells.

Periodically, since 1959, the U. S. Army Research Office has reviewed the status of fuel cells with emphasis on the military developments.

Fuel cells and their progress to date can be best measured and placed in historical perspective when compared to other technical developments. Quoting from the Congressional Record of 1875, eighty-six years ago:

"A new source of power, which burns a distillate of kerosene called gasoline, has been produced by a Boston engineer. Instead of burning the fuel under a boiler, it is exploded inside the cylinder of an engine. This so-called internal combustion engine may be used under certain conditions to supplement steam engines. Experiments are under way to use an engine to propel a vehicle.

"This discovery begins a new era in the history of civilization. It may some day prove to be more revolutionary in the development of human society than the invention of the wheel, the use of metals, or the steam engine. Never in history has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world.

"The dangers are obvious. Stores of gasoline in the hands of the people, interested primarily in profit, would constitute a fire and explosive hazard of the first rank. Horseless carriages propelled by gasoline engines might attain speeds of 14 or even 20 miles per hour. The menace to our people of vehicles of this type hurtling through our streets and along our roads and poisoning the atmosphere would call for prompt legislative action even if the military and economic implications were not so overwhelming. The Secretary of War has testified before us and has pointed out the destructive effects of the use of such vehicles in battle. Furthermore, our supplies of petroleum, from which gasoline can be extracted only in limited quantities, make it imperative that the defense forces should have first call on the limited supply. Furthermore, the cost of producing it is far beyond the financial capacity of private industry, yet the safety of the nation demands that an adequate supply should be produced. In addition, the development of this new power may displace the use of horses, which would wreck our agriculture.

". . . the discovery with which we are dealing involves forces of a nature too dangerous to fit into any of our usual concepts."

These remarks made over 80 years ago are familiar to us involved in fuel cells: the new fuels, their hazards and cost, the military interest, the mobile application, the promise for the future, the present danger, and the probable impact on society.

In attempting to place the 1961 state-of-the-art of fuel cell research, development and technology in perspective, we might go back five years.

In 1956, exploratory work on fuel cells was only being carried out at a few places around the world.

In England, Francis T. Bacon, the dedicated pioneer was working for the Electrical Research Association on the high pressure hydrogen oxygen Bacon System.

In Germany, Professor Justi, the brilliant physicist and inventor, had started to fabricate and test the first Raney nickel D. S. K. metal defect electrodes.

In Russia, Davtyan; in England, Chambers; in Holland, Ketelaar; and Gorin in the United States, were investigating high temperature carbonaceous fuel cells using fused salt electrolytes. In the United States, five years ago, only a few companies were actively engaged in fuel cell research--Consolidation Coal, National Carbon, General Electric, Leeson, and Aerojet.

A modest military program had been started by the United States Navy and the United States Army Signal Corps.

Since that time, in 1961, the fuel cell world-wide effort has grown exponentially. In the United States, over 50 companies are known to be actively engaged.

As an example, more than 40 firms are sponsoring a cooperative fuel cell research program at the Battelle Memorial Institute and represent the chemical, oil, transportation, public utilities, automotive, aircraft, electronics, engine and power plant industries. The fundamental research being carried out at Battelle supplements government and private industry projects. In 1961, government expenditures in fuel cells for military and space application will exceed 4 million dollars. Under government sponsorship, at government installations, universities, non-profit organizations and industry fundamental electrochemical phenomena are being studied, new concepts for space applications are being evaluated, and power plants and engines are being fabricated and tested.

In the United Kingdom, Chambers and Bacon are working under sponsorship of the National Research Development Corporation. The Central Electric Generating Board has a substantial fuel cell program evaluating fuel cells for central power station applications and a number of private companies are studying fuel cell systems, such as, Shell, British-Petroleum, Hawker-Siddley and Chloride.

In Holland, Broers is investigating high temperature systems under T. N. O.'s sponsorship.

In Germany, fuel cell development is carried out by a number of private concerns, such as, Ruhrchemie, A. F. A., Siemens, A. E. G. and at a number of technical institutes, such as, Braunschweig under the direction of Professor Justi, and at Bonn and Munster Universities.

The French government started two years ago a comprehensive fuel cell program and excellent work is being done at the French Petroleum Institute and at French Center of Electrical Research, a number of private companies, such as, St. Gobain, Picheney, Compagnie Sans Fils, and Compagnie Generale D'Electricite are also doing pioneer work in this field. It is known that the Indian government, the Commonwealth of Australia and Japanese public and private interests have fuel cell research programs. Little is known of the Russian and Chinese fuel cell projects.

In the last two years, we have seen the revival and mushrooming of fuel cell research and development throughout the world. What progress has been made?

In 1961, two years after the Fuel Cell Symposium held by the Gas and Fuel Division at the 136th National Meeting of the A. C. S., a hydrogen-oxygen fuel cell system can be purchased from a number of U. S. manufacturers. These engines or power plants range from hundreds of watts to kilowatts and will operate thousands of hours with negligible maintenance at energy efficiencies of the order of 60%.

The U. S. government is testing fuel cells for use in submarines, as secondary power sources for satellites and space vehicles and for ground power generation. These systems are believed to use hydrogen and oxygen as feed gases and operate at temperatures ranging from 20°C. to 200°C. The impetus of military funding has also resulted in the investigation of more exotic and novel systems: biological, regenerative, use of high energy fuels, etc. In 1961, there is a substantial military fuel cell market in the U. S. A.

Substantial progress has taken place in the development of high temperature systems. This type of fuel cell operating on cheap fuels, such as, natural gas, propane, kerosene and air is now being system engineered and tested at the multikilowatt level. Some of the endurance, corrosion, reliability materials and cost problems which plagued the courageous pioneers in 1959 and limited the system utility have been solved. A number of commercial applications exist for this type of ground power supply operating at fuel efficiency of 50% or higher.

At the 1959 Symposium, no mention was made of low temperature fuel cells using medium cost fuels such as hydrazine, ammonia, methanol, ethylene oxide, ethylene glycol or methylamines. Significant results here and abroad have been achieved in the utilization of these fuels using air as an oxidant. This type of fuel cell is economically sound in a number of applications, ranging from industrial storage battery replacement to vehicular power. I believe that in 1962, this type of engine will be commercially available in the United States or overseas.

Handling, storage, logistic and economic problems limit the utility of fuel cells using oxygen at the cathode. Significant progress has been made in 1960 and 1961 as a result of fundamental work on the oxygen electrode. A better understanding of fuel cell electrode reaction mechanisms and structural requirements has resulted in the development of useful practical air electrodes operating in a variety of electrolytes over a wide range of temperatures.

The large acceptance of fuel cells hinges on the use of a cheap and readily available fuel, such as, natural gas, propane or methane in moderate temperatures and pressures fuel cells using air as an oxidant. Significant progress has been achieved towards this goal by a number of organizations such as Esso Research and the French Petroleum Institute. Further progress is dependent on continued basic and fundamental research in electrode reactions and kinetics and surface catalysis leading to a better understanding of the rate determining processes.

The practical and commercial criteria for a fuel cell power plant can be readily defined as a function of intended application: high efficiency, low capital cost, minimum upkeep, long life, etc. Some of these criteria are met by existing already engineered systems.

Energy efficiency in a fuel cell power plant is independent of size. The impact of this concept will not be fully felt in the United States, United Kingdom or Western Europe, but might well create a technical revolution in the under-developed countries of the world. These countries need electrical power and do not have the time or the capital to build large power plants and create distribution networks. Small fuel cell power stations will help our friends and neighbors living in the under-developed countries.

The growth of fuel cell technology will be felt in many areas and affect many industries. As an example, in the PAU region of France, deposits of Bauxite and fields of natural gas are contiguous; in Venezuela, iron ore and oil fields. The marriage of natural resources together with the fuel cell will certainly create new economic and industrial climates.

The petroleum industry and natural gas industry might be profoundly changed with the coming of age of fuel cell power plants in stationary or mobile applications. These might range from shifts in production methods to reduced fuel requirements in the U. S. A. where the natural gas pipelines sometime parallel and in other cases supplement the electrical power grid competition between these public utilities might result in profound changes in local economies.

The increase in research, development engineering that has taken place since our last symposium two years ago assures us that fuel cells will become successful and competitive electrical power sources in a variety of applications within the next few years.

Quoting again from the 1875 Congressional Records,

"Never in history has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and the peace of the world."